mri_dat_analysis_five

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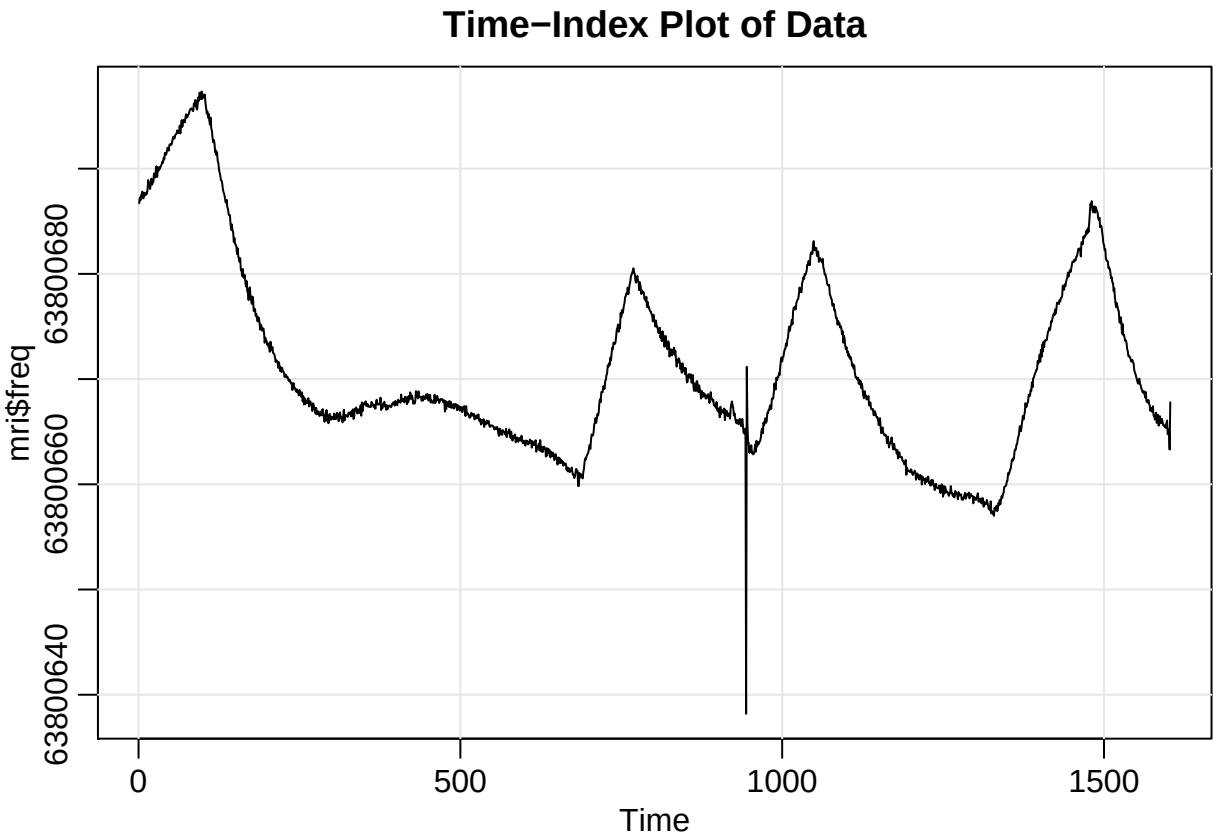
7/20/2018

Data Prep + EDA

```
#read in the data
mri <- read.csv("/Users/panders2/Documents/schools/tamu/stat_626/project/stat_626_proj/mri_dat_one.csv")
names(mri) <- c("hour", "minute", "freq", "int_pressure", "atm_pressure", "tot_pressure", "tesla")
str(mri)
```

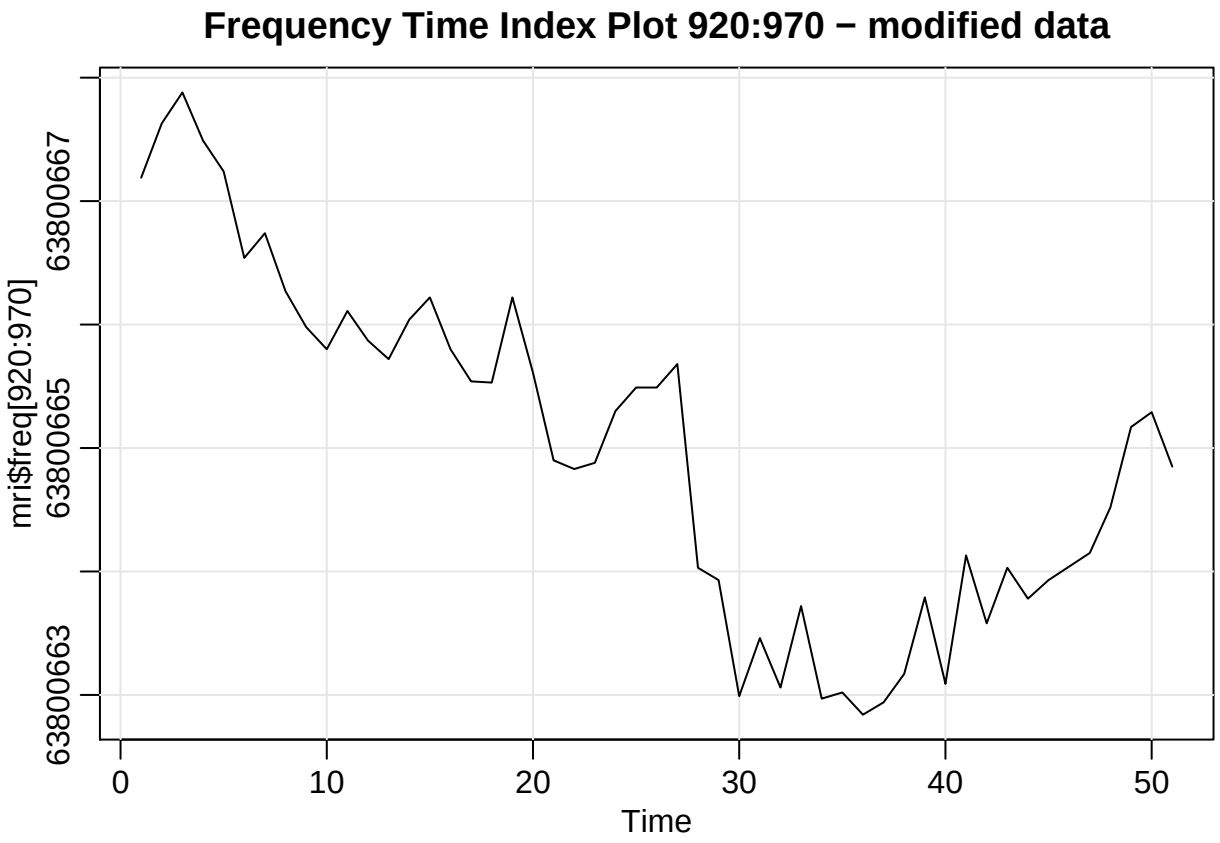
```
## 'data.frame':    1603 obs. of  7 variables:
##  $ hour        : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ minute      : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ freq        : num  63800687 63800687 63800687 63800687 63800688 ...
##  $ int_pressure: num  2.95 2.95 2.96 2.97 2.97 ...
##  $ atm_pressure: num  14.7 14.7 14.7 14.7 14.7 ...
##  $ tot_pressure: num  17.6 17.6 17.6 17.6 17.7 ...
##  $ tesla       : num  1.5 1.5 1.5 1.5 1.5 ...
```

```
astsa::tsplot(mri$freq, main="Time-Index Plot of Data")
```

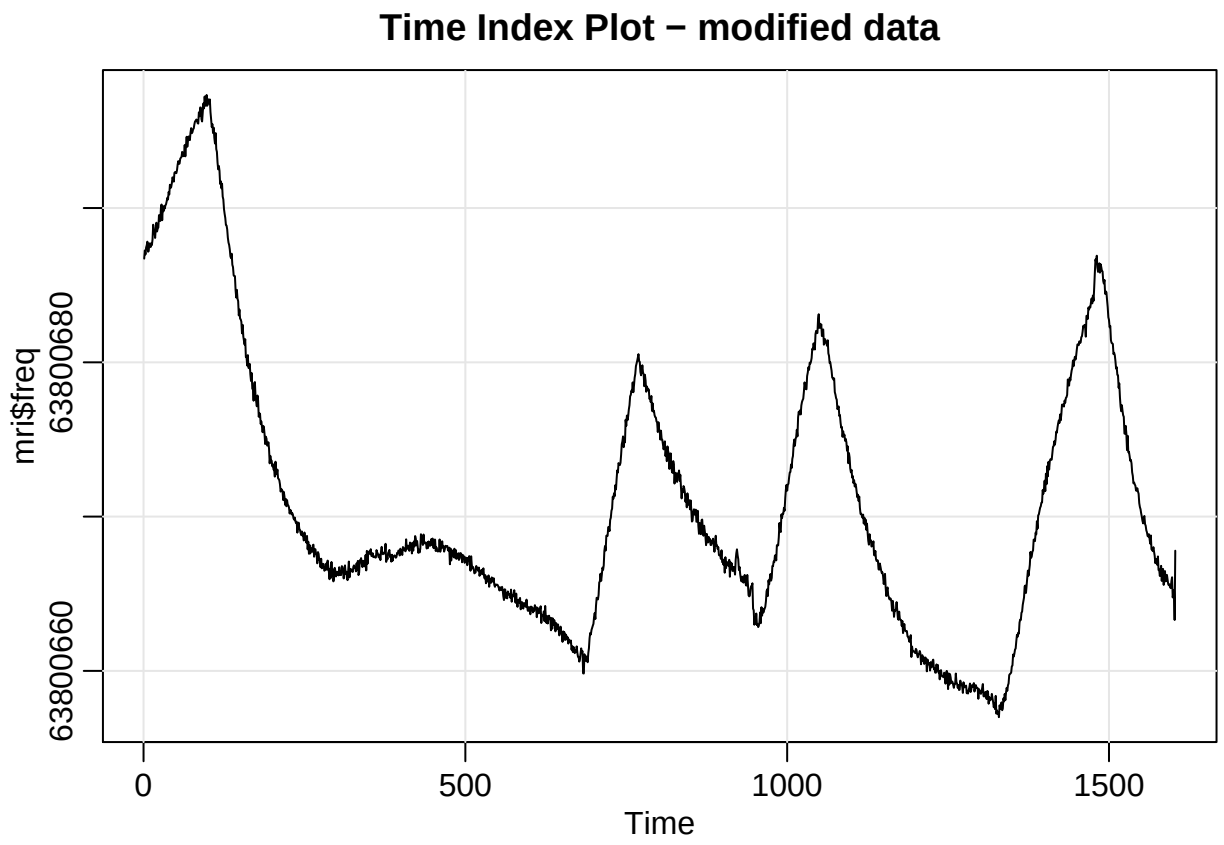



```
mri$freq[944] <- ((mri$freq[943] + mri$freq[946]) / 2)
mri$freq[945] <- ((mri$freq[943] + mri$freq[946]) / 2)
```

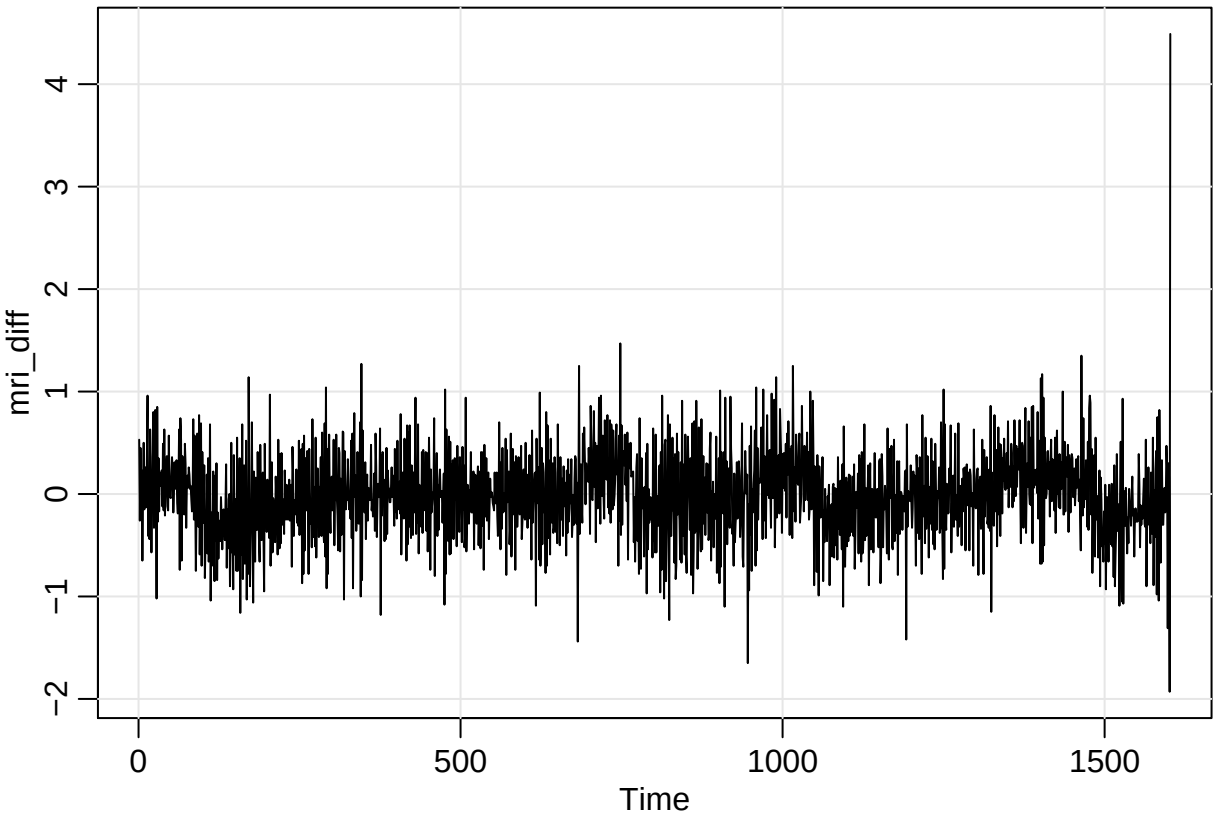
```
astsa::tsplot(mri$freq[920:970], main="Frequency Time Index Plot 920:970 - modified data")
```




```
astsa::tsplot(mri$freq, main="Time Index Plot - modified data")
```




```
mri_diff <- diff(mri$freq)
astsa::tsplot(mri_diff)
```



Formal Tests for Stationarity

Run the differenced series through the battery of unit root tests we learned about.

```
# Dickey-Fuller Test
tseries::adf.test(mri_diff, k=0)
```

```
## Warning in tseries::adf.test(mri_diff, k = 0): p-value smaller than printed
## p-value
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  mri_diff
## Dickey-Fuller = -56.027, Lag order = 0, p-value = 0.01
## alternative hypothesis: stationary
```

```
# Augmented Dickey-Fuller Test
tseries::adf.test(mri_diff)
```

```
## Warning in tseries::adf.test(mri_diff): p-value smaller than printed p-
## value
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  mri_diff
## Dickey-Fuller = -3.991, Lag order = 11, p-value = 0.01
## alternative hypothesis: stationary
```

```
# phillips-peron test
tseries::pp.test(mri_diff)
```

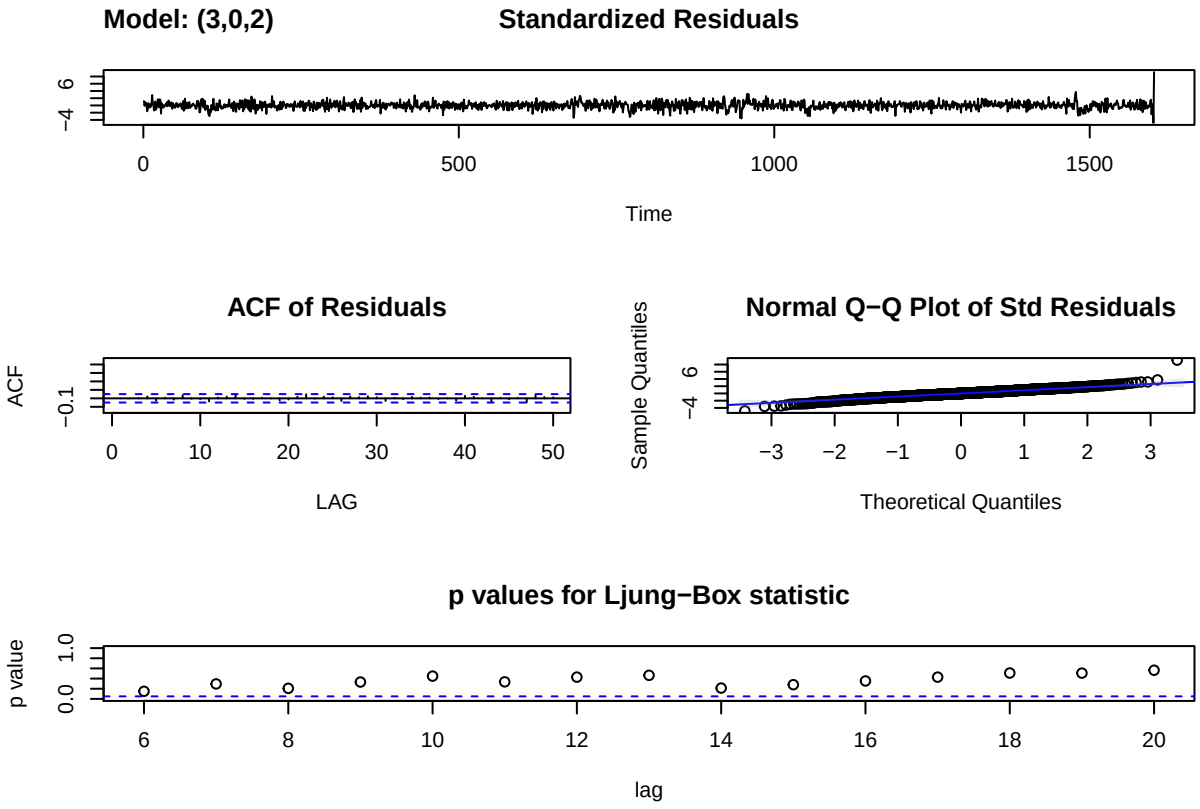
```
## Warning in tseries::pp.test(mri_diff): p-value smaller than printed p-value
```

```
##
##  Phillips-Perron Unit Root Test
##
## data:  mri_diff
## Dickey-Fuller Z(alpha) = -2877.6, Truncation lag parameter = 8,
## p-value = 0.01
## alternative hypothesis: stationary
```

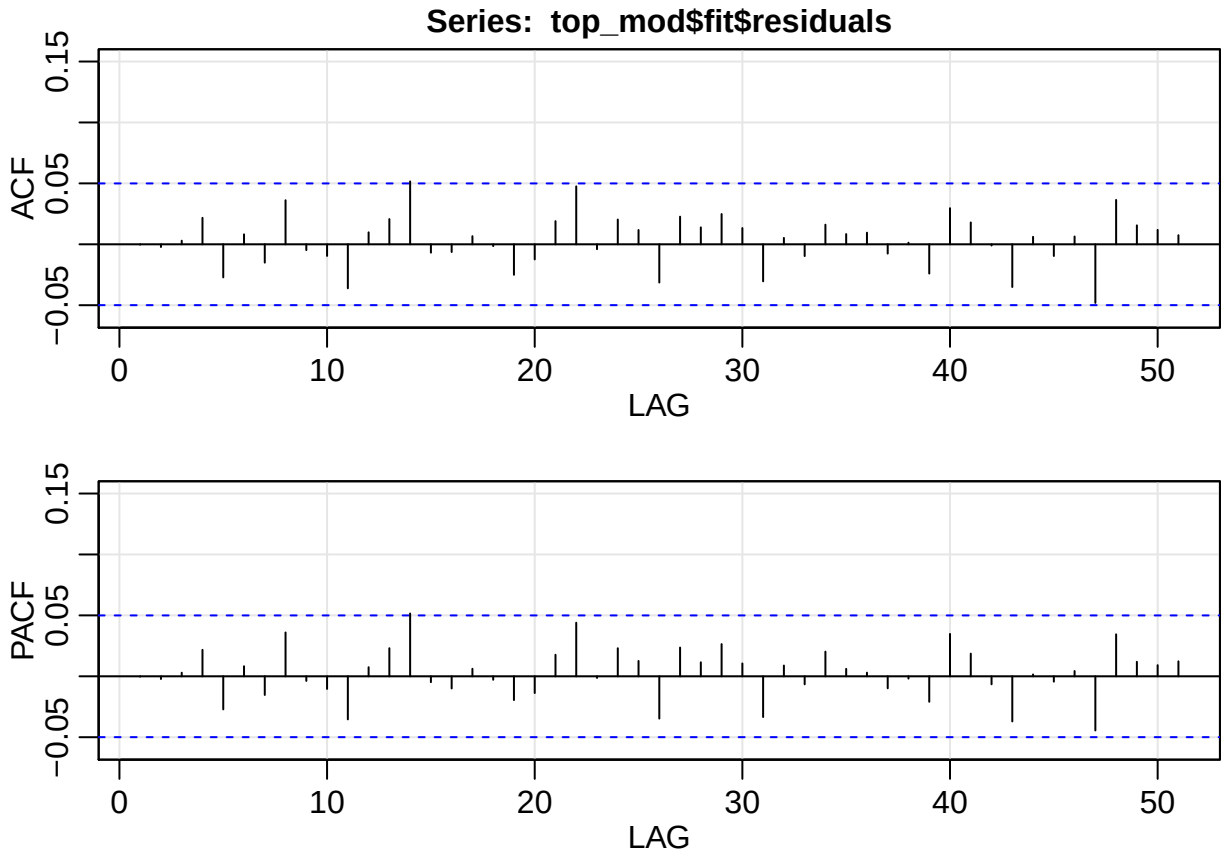
ARIMA Fit

Running the model we came up with previously.

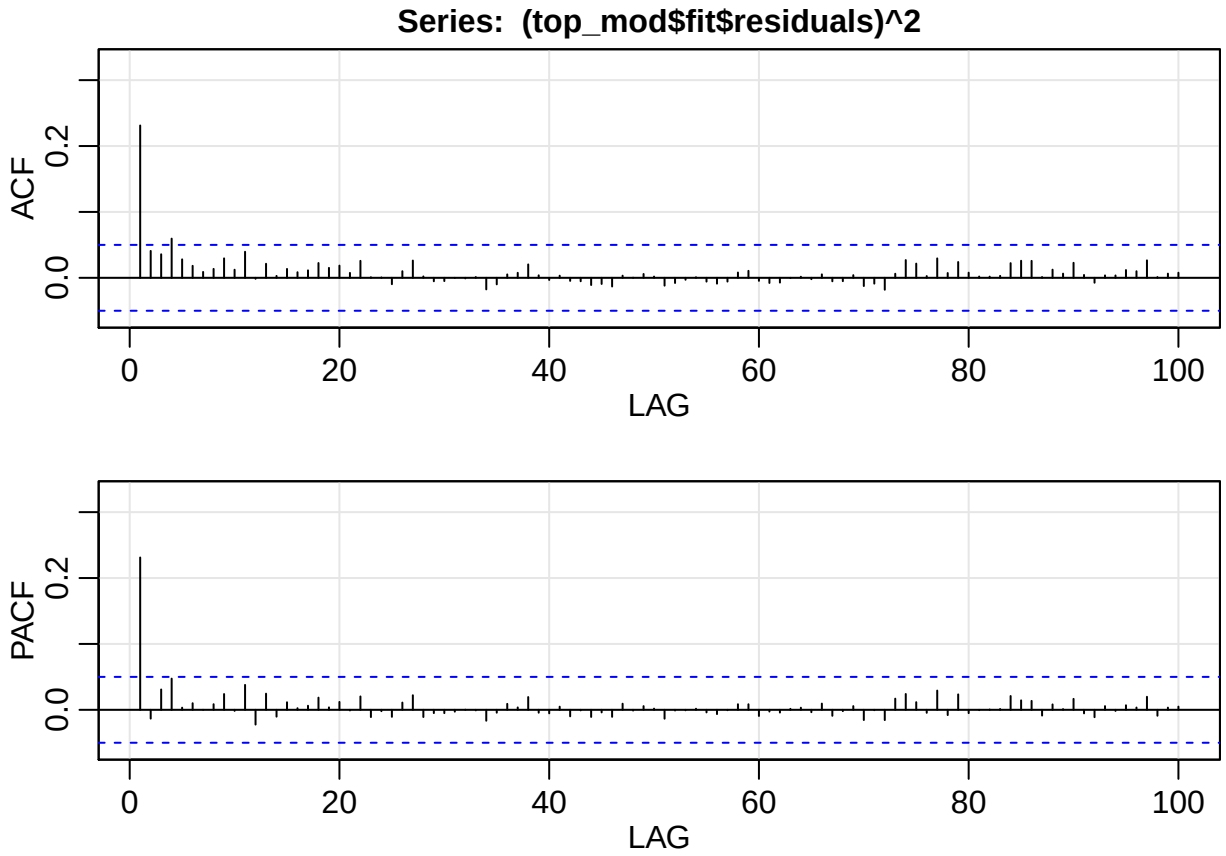
```
top_mod <- sarima(mri_diff, 3,0,2)
```




```
acf2(top_mod$fit$residuals)
```

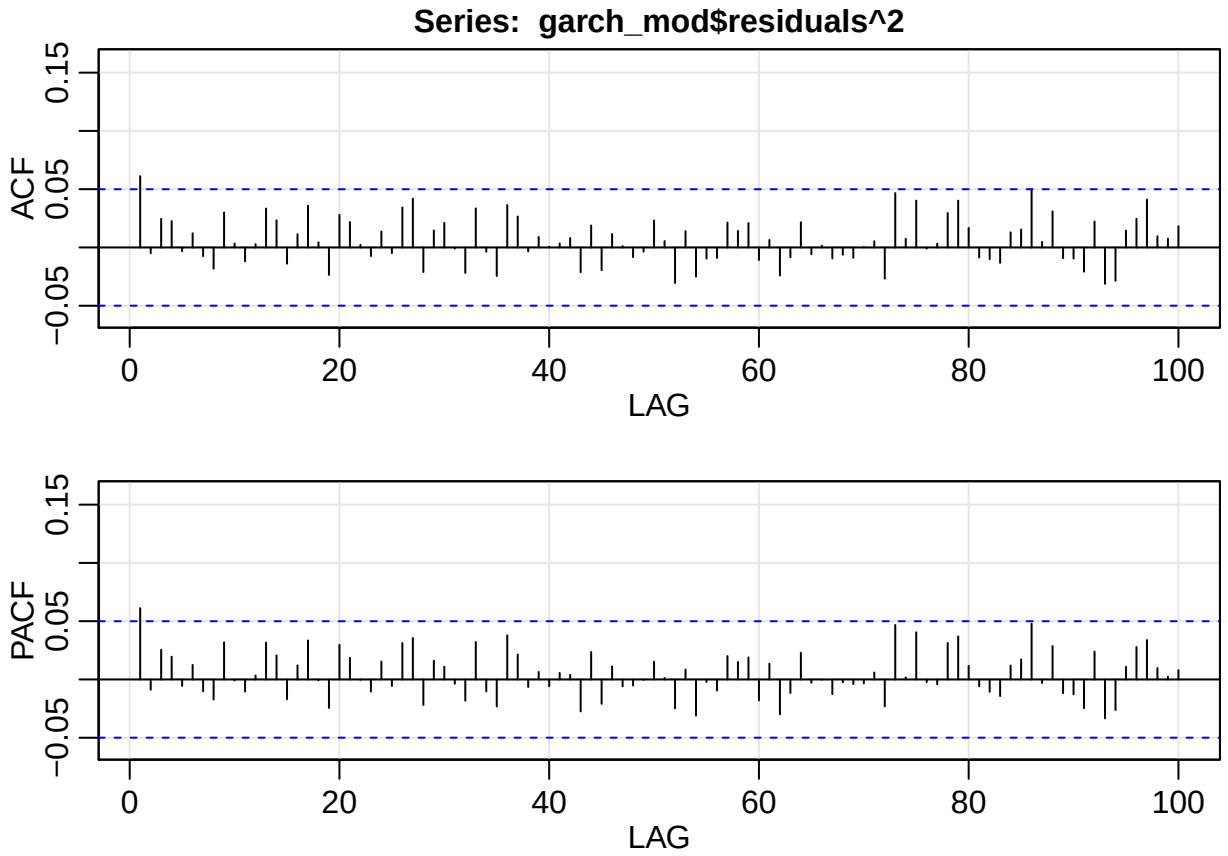



```
acf2((top_mod$fit$residuals)^2, 100)
```



It honestly doesn't look like there is much to worry about here. Regardless, let's fit an ARCH.

```
garch_mod <- tseries::garch(mri_diff, trace=F)
summary(garch_mod)
acf2(garch_mod$residuals^2, 100)
```




```
summary(garch_mod2 <- fGarch::garchFit(~arma(1,0)+garch(1,0), mri_diff))
```

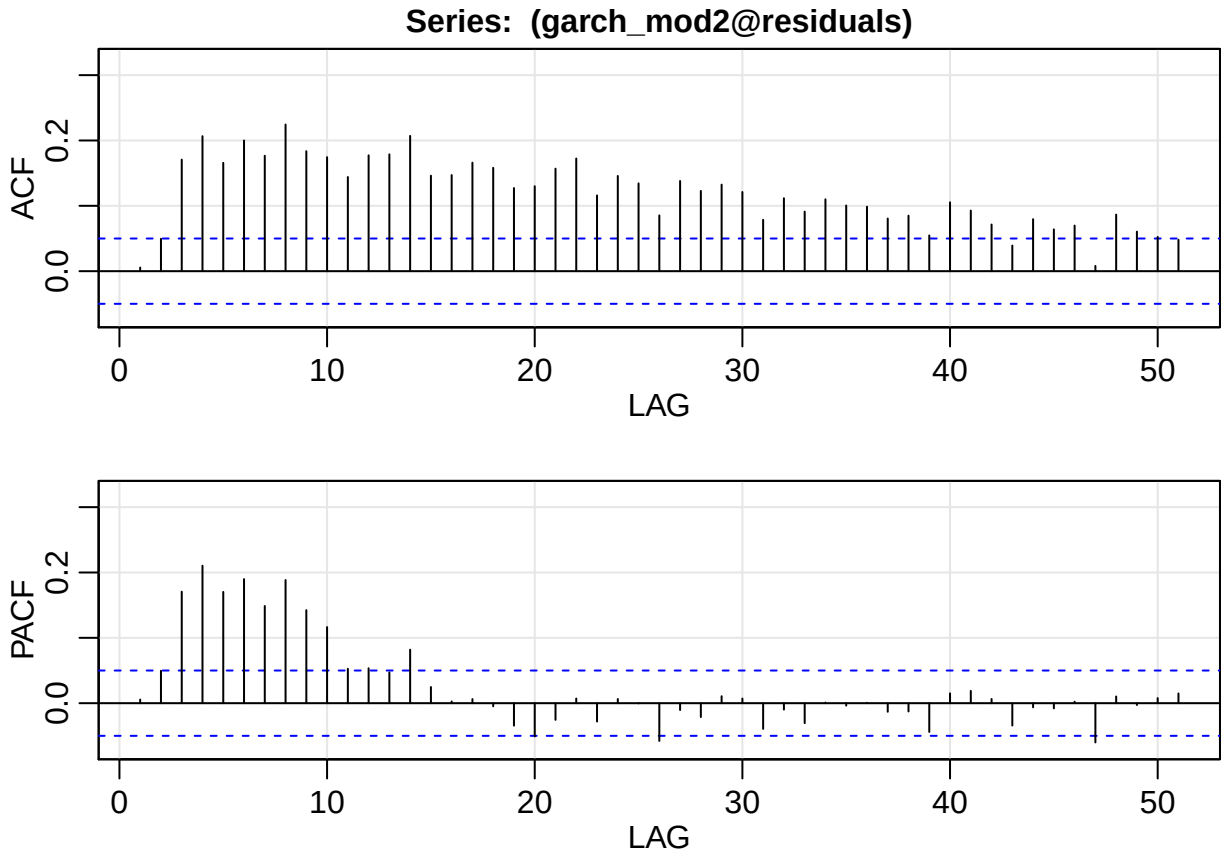
```
##
## Series Initialization:
##  ARMA Model:                 arma
##  Formula Mean:               ~ arma(1, 0)
##  GARCH Model:                garch
##  Formula Variance:           ~ garch(1, 0)
##  ARMA Order:                 1 0
##  Max ARMA Order:             1
##  GARCH Order:                1 0
##  Max GARCH Order:            1
##  Maximum Order:              1
##  Conditional Dist:           norm
##  h.start:                    2
##  llh.start:                  1
##  Length of Series:           1602
##  Recursion Init:             mci
##  Series Scale:               0.453808
##
## Parameter Initialization:
##  Initial Parameters:          $params
##  Limits of Transformations:   $U, $V
##  Which Parameters are Fixed?  $includes
##  Parameter Matrix:
##                       U          V      params includes
##     mu     -0.26038501   0.260385 -0.02785916     TRUE
```

```
##     ar1    -0.99999999   1.000000 -0.35590223     TRUE
##     omega   0.00000100 100.000000  0.10000000     TRUE
##     alpha1  0.00000001   1.000000  0.10000000     TRUE
##     gamma1 -0.99999999   1.000000  0.10000000    FALSE
##     delta   0.00000000   2.000000  2.00000000    FALSE
##     skew    0.10000000  10.000000  1.00000000    FALSE
##     shape   1.00000000  10.000000  4.00000000    FALSE
##  Index List of Parameters to be Optimized:
##     mu    ar1  omega alpha1
##      1      2      3      4
##  Persistence:                  0.1
##
##
## --- START OF TRACE ---
## Selected Algorithm: nlminb
##
## R coded nlminb Solver:
##
##   0:     4516.1742: -0.0278592 -0.355902 0.100000 0.100000
##   1:     2214.6821: -0.0278663 -0.362244  1.06233 0.371812
##   2:     2196.3734: -0.0305564 -0.357994  1.14678 1.00000e-08
##   3:     2184.5519: -0.0388771 -0.295280 0.938526 0.317145
##   4:     2161.2337: -0.0388813 -0.329491 0.859566 0.248492
##   5:     2147.7616: -0.0388939 -0.376603 0.705664 0.0982636
##   6:     2144.2980: -0.0388967 -0.366397 0.731821 0.128466
##   7:     2143.9720: -0.0389012 -0.360430 0.743734 0.135492
##   8:     2143.9501: -0.0389061 -0.349836 0.753445 0.130982
##   9:     2143.9093: -0.0389122 -0.356972 0.753770 0.129501
##  10:     2143.9090: -0.0389195 -0.356994 0.754381 0.129784
##  11:     2143.9088: -0.0389320 -0.357004 0.754287 0.129243
##  12:     2143.9085: -0.0389472 -0.356963 0.754548 0.129594
##  13:     2143.8657: -0.0441451 -0.356606 0.751439 0.131816
##  14:     2143.8620: -0.0441488 -0.358209 0.754035 0.130106
##  15:     2143.8610: -0.0442364 -0.357245 0.754025 0.129992
##  16:     2143.8573: -0.0456948 -0.357423 0.754150 0.129938
##  17:     2143.8570: -0.0462669 -0.357403 0.753989 0.130095
##  18:     2143.8570: -0.0462658 -0.357404 0.754000 0.130087
##
## Final Estimate of the Negative LLH:
##  LLH:  878.147    norm LLH:  0.5481567
##          mu         ar1       omega      alpha1
## -0.02099578 -0.35740387  0.15527999  0.13008713
##
## R-optimhess Difference Approximated Hessian Matrix:
##                mu         ar1       omega      alpha1
## mu     -9405.9135   178.00425    176.4039  -189.19081
## ar1      178.0043 -1509.71515    104.3818   -91.96185
## omega    176.4039   104.38185 -27354.2443 -2867.81295
## alpha1  -189.1908   -91.96185  -2867.8130 -1512.09391
## attr(,"time")
## Time difference of 0.01478696 secs
##
## --- END OF TRACE ---
##
```

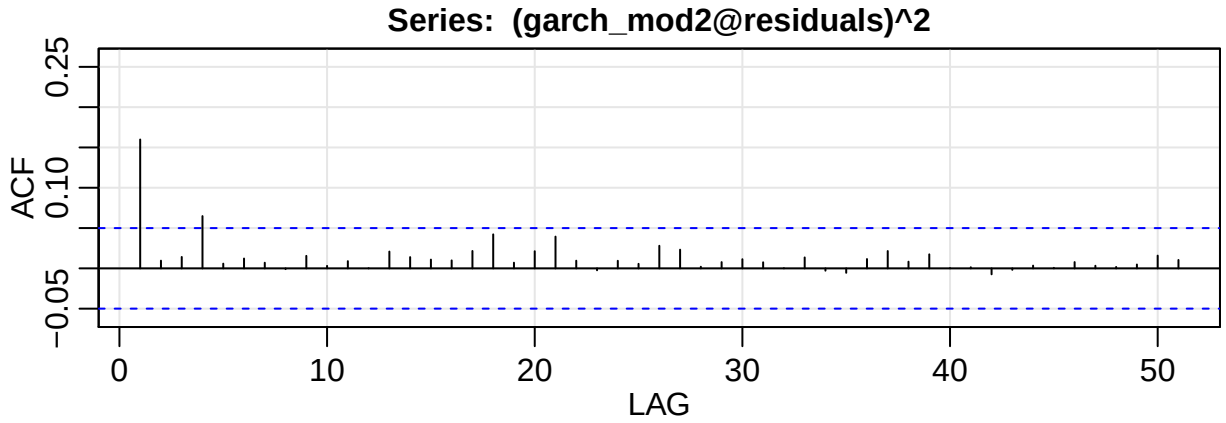
```
##
## Time to Estimate Parameters:
##  Time difference of 0.07713604 secs
##
## Title:
##  GARCH Modelling
##
## Call:
##  fGarch::garchFit(formula = ~arma(1, 0) + garch(1, 0), data = mri_diff)
##
## Mean and Variance Equation:
##  data ~ arma(1, 0) + garch(1, 0)
## <environment: 0x7f9756ad86a8>
##  [data = mri_diff]
##
## Conditional Distribution:
##  norm
##
## Coefficient(s):
##        mu        ar1      omega     alpha1
## -0.020996  -0.357404   0.155280   0.130087
##
## Std. Errors:
##  based on Hessian
##
## Error Analysis:
##         Estimate  Std. Error  t value Pr(>|t|)
## mu     -0.020996    0.010345   -2.029   0.0424 *
## ar1    -0.357404    0.025850  -13.826  < 2e-16 ***
## omega   0.155280    0.006768   22.942  < 2e-16 ***
## alpha1  0.130087    0.028876    4.505 6.64e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
##  -878.147    normalized:  -0.5481567
##
## Description:
##  Sat Jul 21 10:59:23 2018 by user:
##
##
## Standardised Residuals Tests:
##                                 Statistic p-Value
##  Jarque-Bera Test   R    Chi^2  31.17015  1.704072e-07
##  Shapiro-Wilk Test  R    W      0.99636   0.0007360705
##  Ljung-Box Test     R    Q(10)  511.7921  0
##  Ljung-Box Test     R    Q(15)  775.8133  0
##  Ljung-Box Test     R    Q(20)  969.0052  0
##  Ljung-Box Test     R^2  Q(10)  22.96918  0.0108609
##  Ljung-Box Test     R^2  Q(15)  29.58453  0.01351105
##  Ljung-Box Test     R^2  Q(20)  40.49364  0.004324356
##  LM Arch Test       R    TR^2   25.82264  0.01137129
##
## Information Criterion Statistics:
```

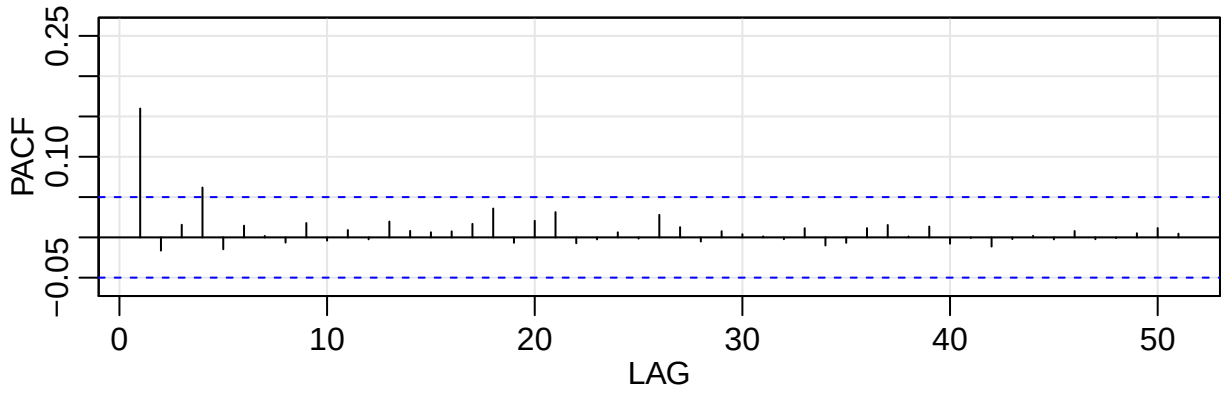
```
##       AIC       BIC       SIC      HQIC
## 1.101307 1.114738 1.101295 1.106294
```

```
acf2((garch_mod2@residuals))
```




```
acf2((garch_mod2@residuals)^2)
```






```
summary(garch_mod3 <- fGarch::garchFit(~garch(1,1), mri_diff))
```

```
##
## Series Initialization:
##  ARMA Model:                 arma
##  Formula Mean:               ~ arma(0, 0)
##  GARCH Model:                garch
##  Formula Variance:           ~ garch(1, 1)
##  ARMA Order:                 0 0
##  Max ARMA Order:             0
##  GARCH Order:                1 1
##  Max GARCH Order:            1
##  Maximum Order:              1
##  Conditional Dist:           norm
##  h.start:                    2
##  llh.start:                  1
##  Length of Series:           1602
##  Recursion Init:             mci
##  Series Scale:               0.453808
##
## Parameter Initialization:
##  Initial Parameters:           $params
##  Limits of Transformations:    $U, $V
##  Which Parameters are Fixed?   $includes
##  Parameter Matrix:
##                      U          V     params includes
##     mu     -0.26038501   0.260385 -0.0260385     TRUE
```

```
##     omega   0.00000100 100.000000  0.1000000     TRUE
##     alpha1  0.00000001   1.000000  0.1000000     TRUE
##     gamma1 -0.99999999   1.000000  0.1000000    FALSE
##     beta1   0.00000001   1.000000  0.8000000     TRUE
##     delta   0.00000000   2.000000  2.0000000    FALSE
##     skew    0.10000000  10.000000  1.0000000    FALSE
##     shape   1.00000000  10.000000  4.0000000    FALSE
##  Index List of Parameters to be Optimized:
##     mu  omega alpha1  beta1
##      1      2      3      5
##  Persistence:                  0.9
##
##
## --- START OF TRACE ---
## Selected Algorithm: nlminb
##
## R coded nlminb Solver:
##
##   0:     2234.4297: -0.0260385 0.100000 0.100000 0.800000
##   1:     2234.2555: -0.0260386 0.102463 0.100749 0.800912
##   2:     2234.1468: -0.0260388 0.103442 0.0991398 0.798935
##   3:     2233.9475: -0.0260394 0.108643 0.0986231 0.797350
##   4:     2233.5074: -0.0260406 0.114237 0.0980476 0.787985
##   5:     2232.2995: -0.0260472 0.136780 0.122868 0.745377
##   6:     2231.1489: -0.0260599 0.174683 0.103995 0.711514
##   7:     2230.7835: -0.0260600 0.178606 0.108296 0.714041
##   8:     2230.6224: -0.0260642 0.180371 0.108533 0.707952
##   9:     2228.8803: -0.0261961 0.281664 0.113274 0.600510
##  10:     2226.7019: -0.0268942 0.340448 0.173869 0.482163
##  11:     2226.2289: -0.0302629 0.389059 0.179529 0.430008
##  12:     2226.0256: -0.0332671 0.439080 0.180051 0.373170
##  13:     2226.0075: -0.0323357 0.447354 0.178400 0.368201
##  14:     2226.0067: -0.0328125 0.448197 0.177524 0.368277
##  15:     2226.0067: -0.0326494 0.448334 0.177510 0.368103
##  16:     2226.0067: -0.0326606 0.448312 0.177513 0.368115
##  17:     2226.0067: -0.0326608 0.448312 0.177512 0.368116
##
## Final Estimate of the Negative LLH:
##  LLH:  960.2967    norm LLH:  0.5994361
##          mu       omega      alpha1       beta1
## -0.01482171  0.09232603  0.17751197  0.36811587
##
## R-optimhess Difference Approximated Hessian Matrix:
##                 mu       omega     alpha1        beta1
## mu     -9786.98650    349.2145  -152.7304     68.10489
## omega    349.21449 -58590.4555 -7183.4424 -11206.04530
## alpha1  -152.73036  -7183.4424 -2082.0565  -1521.98229
## beta1     68.10489 -11206.0453 -1521.9823  -2234.18209
## attr(,"time")
## Time difference of 0.01249099 secs
##
## --- END OF TRACE ---
##
##
```

```
## Time to Estimate Parameters:
##  Time difference of 0.2886679 secs
##
## Title:
##  GARCH Modelling
##
## Call:
##  fGarch::garchFit(formula = ~garch(1, 1), data = mri_diff)
##
## Mean and Variance Equation:
##  data ~ garch(1, 1)
## <environment: 0x7f9755be54e0>
##  [data = mri_diff]
##
## Conditional Distribution:
##  norm
##
## Coefficient(s):
##        mu      omega     alpha1      beta1
## -0.014822   0.092326   0.177512   0.368116
##
## Std. Errors:
##  based on Hessian
##
## Error Analysis:
##         Estimate  Std. Error  t value Pr(>|t|)
## mu      -0.01482     0.01013   -1.463  0.14344
## omega    0.09233     0.02137    4.320 1.56e-05 ***
## alpha1   0.17751     0.03234    5.489 4.04e-08 ***
## beta1    0.36812     0.11737    3.136  0.00171 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Log Likelihood:
##  -960.2967    normalized:  -0.5994361
##
## Description:
##  Sat Jul 21 10:59:24 2018 by user:
##
##
## Standardised Residuals Tests:
##                                 Statistic p-Value
##  Jarque-Bera Test   R    Chi^2  24.49474  4.79773e-06
##  Shapiro-Wilk Test  R    W      0.9964386 0.0008888356
##  Ljung-Box Test     R    Q(10)  315.3108  0
##  Ljung-Box Test     R    Q(15)  390.7939  0
##  Ljung-Box Test     R    Q(20)  444.4547  0
##  Ljung-Box Test     R^2  Q(10)  10.56184  0.3926566
##  Ljung-Box Test     R^2  Q(15)  14.36199  0.498271
##  Ljung-Box Test     R^2  Q(20)  18.69053  0.5420157
##  LM Arch Test       R    TR^2   12.96503  0.3715879
##
## Information Criterion Statistics:
##      AIC      BIC      SIC     HQIC
```

```
## 1.203866 1.217297 1.203854 1.208853
```